Improving TIMES-Ukraine for LEDS: Methodology for Adding Non-Energy GHG Emissions Accounting

Submitted to

International Resources Group

Prime Contractor to

U.S. Agency for International Development

For the

Municipal Energy Reform Project

Contract Number: AID-OAA-I-13-00015/AID-121-TO-13-00006

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Energy, Economy and Environment

November 12, 2014

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Acronyms

BAU	Business-as-Usual
CH_4	Methane
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2eq	Carbon Dioxide equivalent
DWG	DecisionWare Group
EC-LEDS	Enhanced Capacity – Low Emissions Development Strategy
GDP	Gross Domestic Product
Gg	Gigagrams
GWh	Gigawatt Hours
GWP	Global Warming Potential
GHG	Greenhouse Gas
HFC	Hydroflourocarbons
IEF/UNAS	Institute for Economics and Forecasting of Ukrainian National Academy of Sciences
Kt	Thousand metric tons
Ktoe	Thousand Tons Oil Equivalent
LDV	Light Duty Vehicle
LEDS	Low Emission Development Strategies
LFG	Land-fill Gas
MARKAL	MARKet ALlocation
MERP	Municipal Energy Reform Project
MW	Megawatts
N_2O	Nitrous Oxide
NOx	Nitric Oxides
NMVOC	Non-methane volatile organic compounds
PFC	Perfluorinated compounds
PJ	Petajoules
PJa	Petajoules per annum
REDS	Renewable Energy Development Strategies
RES	Reference Energy System
SF6	Sulfur hexafluoride
t	metric tons
TIMES	The Integrated MARKAL/EFOM System
UNFCCC	United Nations Framework Convention on Climate Change
USAID	US Agency for International Development

1 Executive Summary

This report has been prepared under the Ukraine Municipal Energy Reform Project (MERP), which is funded by the U.S. Agency for International Development. The report describes the methodology proposed for incorporating full energy sector Greenhouse Gas (GHG) accounting into the TIMES[1]-Ukraine model to enable it to fully support planning for low emission development strategies (LEDS) and renewable energy development strategies (REDS).

The TIMES-Ukraine model currently accounts for all energy-related GHG emissions, and has been used to examine energy sector policy and strategy issues. Expanding the model to incorporate non-energy sector emissions and mitigation measures will enable it to be used as an integrating framework that can look across all sources of GHG emissions and identify the most cost-effective mitigation approaches that will meet national LEDS-REDS objectives.

There are two main thrusts to the recommended accounting improvements needed in TIMES-Ukraine to achieve full GHG accounting. The addition of non-energy related GHG emission sources, and the development of appropriate mitigation measures.

The TIMES-Ukraine model generates its own business-as-usual emission scenario for the energy sector, as these are directly related to the energy flows. The current model also handles energy system carbon dioxide (CO_2) mitigation measures, as fuel switching and device efficiency are a core feature of TIMES models. However, it currently has no measures defined for mitigation of the significant methane (CH_4) emissions from energy supply activities, such as coal mining and natural gas production. These mitigation measures need to be developed based on Ukraine-specific data, and the report contains a data requirements section outlining the needed data.

Non-energy GHG emissions are usually categorized according to the following 4 categories:

1. Industrial processes – non-energy emissions from industrial production processes for cement, chemicals, iron and steel, and others.
2. Agriculture – emissions related to enteric fermentation, manure management and soil management.
3. Land use and Forestry – emissions and reductions from current land use, changes in land use and forests.
4. Waste – emissions from solid waste handling and waste water treatment.

This report covers the methodology for all non-energy sectors, although MERP plans to only implement the non-CO_2 mitigation measures and the Industrial Process emission sources and mitigation measures.

[1] Integrated energy system planning platform develop under the auspice of the International Energy Agency's Energy Technology Systems Analysis Program (IEA-ETSAP), http://www.iea-etsap.org/web/Times.asp.

The report examines the official 2012 GHG inventory for Ukraine and identifies the key subsectors that are sources of GHG emissions. It then examines each key subsector to identify how to best represent the business-as-usual (BAU) emission profile into TIMES-Ukraine. For the Industrial processes emissions, the BAU emissions levels will be directly tied, using emission intensity factors derived from 2012 data, to the projected industrial activity levels that already exist in the model. For the other non-energy sectors, the BAU emission levels would need to be developed outside the model by a sector expert and input to the model in the form of projected emission levels over time. However, as mentioned above the Agriculture, Land Use and waste sectors will not be introduced into TIMES-Ukraine as part of MERP.

The non-CO_2 and the non-energy GHG mitigations measures need to be developed by sector experts who can identify likely mitigation measures and estimate their cost and performance over time. Once these new emission sources and mitigation measures are fully developed, the TIMES-Ukraine model can be used to identify the set of GHG mitigation strategies, across both the energy and industrial process sectors, which can most cost-effectively meet Ukraine's LEDS-REDS objectives.

2 Background

Task 1 of the DecisionWare Group (DWG) work plan for the Ukraine Municipal Energy Reform Project (MERP) is to assist the Institute for Economics and Forecasting of the Ukrainian National Academy of Sciences (IEF/UNAS) in updating TIMES-Ukraine model for LEDS-REDS analysis. The TIMES-Ukraine model currently accounts for all energy-related CO_2, CH_4 and N_2O emission sources, but to fully support LEDS-REDS planning, the model will be improved to include non-energy industrial sector GHG emissions and reflect CO2eq in the model.

The objective of Task 1 is to prepare TIMES-Ukraine with full energy and industry GHG accounting so that it can be used as an integrated framework that can look across all these sources of GHG emissions to identify the most cost-effective mitigation strategies that will meet national LEDS objectives.

The initial focus of this task has been to determine what data is available for the non-energy sectors that generate GHG emissions in Ukraine, identify approaches to implement non-energy GHG emission sources based on established BAU projections, or proxy data if these are not yet available, develop a list of potentially relevant mitigation options, and identify the mitigation cost data for these measures, which should be developed by local experts. This report summarizes that work and recommends a methodology and approach for implementing full-GHG emissions accounting into the TIMES-Ukraine model.

3 TIMES-Ukraine Overview

With support from several U.S. Agency for International Development (USAID) regional projects, comprehensive national energy planning models were developed for most of the countries in

Southeast Europe and Eurasia. The planning models were designed to support policy making and analysis of future energy investment options. The modeling platform used is the MARKAL/TIMES integrated energy system model, developed under the auspices of the International Energy Agency's Energy Technology Systems Analysis Program (www.iea-etsap.org). The resulting TIMES-Ukraine model has been used to examine the role of energy efficiency and renewable energy in meeting anticipated Energy Community commitments and European Union accession directives, as well as to examine national energy strategy as a whole. The model, recently updated by IEF/UNAS, is used on a regular basis to advise energy sector policy and planning.

A typical TIMES model, as represented by a Reference Energy System (RES) network, is shown in Figure 1. Key features of TIMES models are:

- Encompasses an ***entire energy system*** from resource extraction through to end-use demands;
- Employs least-cost ***optimization;***
- Identifies the most ***cost-effective*** pattern of resource use and technology deployment over time;
- Provides a framework for the evaluation of mid-to-long-term ***policies and programs*** that can impact the evolution of the energy system;
- Quantifies the ***costs and technology choices, and the associated emissions,*** that result from imposition of the policies and programs, and
- Fosters ***stakeholder buy-in*** and consensus building.

For LEDS, the RES will be expanded to track GHG emissions from non-CO_2 energy and industrial sources, and a suite of additional emission reduction options will be added to enable the TIMES-Ukraine model to take a comprehensive look at GHG mitigation potential from the energy and industrial sectors for Ukraine, and help with prioritizing programs and actions to reduce those emissions.

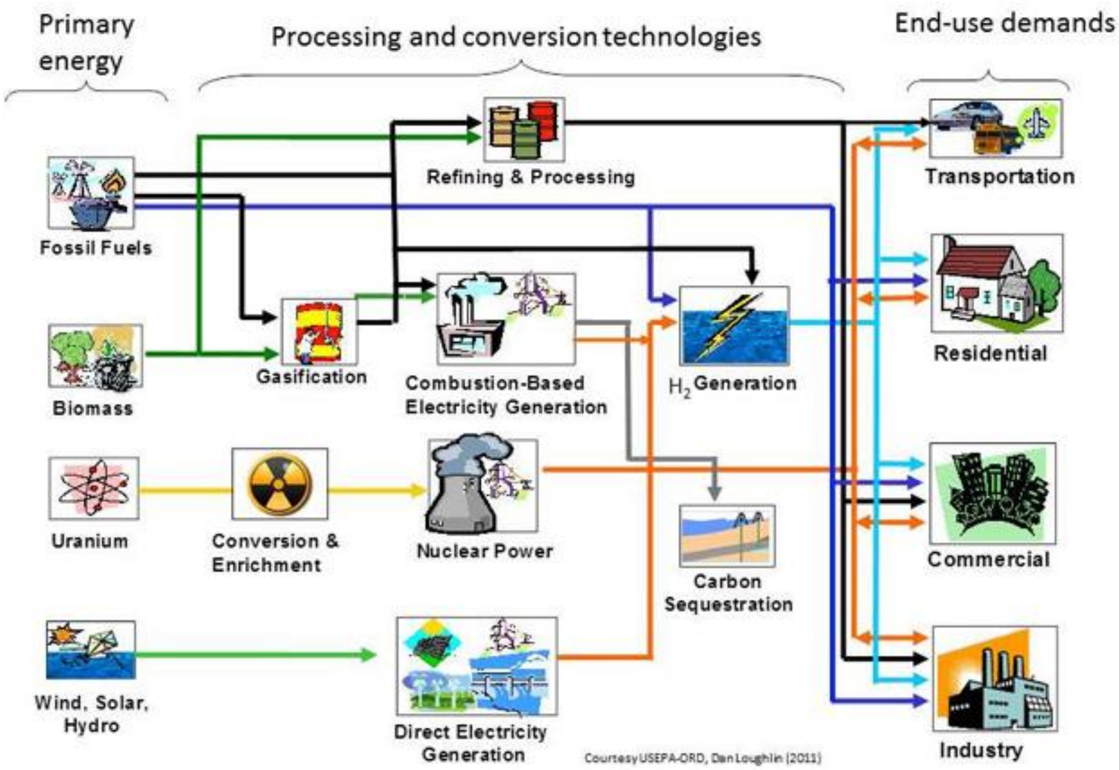

Figure 1: Simplified Reference Energy System

4 Methodology

The starting point for incorporating non-energy GHG emissions into TIMES-Ukraine is the draft 2012 National GHG Inventory submitted by Ukraine to the UNFCCC and downloaded from the UNFCCC web site for Ukraine. That document identifies four non-energy GHG sectors that are important to Ukraine, as shown in Table 1. These sectors are Industrial Processes, Agriculture, Land Use Change and Forestry, and Waste. The approach proposed for each sector is described in the following sections, though only the non-CO_2 GHG emission from energy and industrial sectors will be incorporated initially. Note that the Forestry/Land Use sector produces net reductions in CO_2 emissions.

The GHG inventory includes emissions from NOx, CO and NMVOCs, which have an indirect GHG effect. In accordance with other EC-LEDS activities, only the direct GHG emissions are tracked and included in LEDS assessments, and under MERP, the focus will be all energy sector GHG emissions and the non-energy GHG emissions from industrial processes.

For each sector, the methodology addresses current 2012 emission levels, the approach to developing the BAU projection of future emissions, and the types of mitigation technologies to be considered. The BAU emission levels will be inputs to TIMES-Ukraine, either in the form of projected emission levels over time, or in the form of emission intensity factors that can be tied to activity levels already existing in the model. In some cases, these BAU emission levels will be linked to drivers within the TIMES-Ukraine model, such as GDP or population growth, to allow alternate scenarios to be examined in a consistent manner.

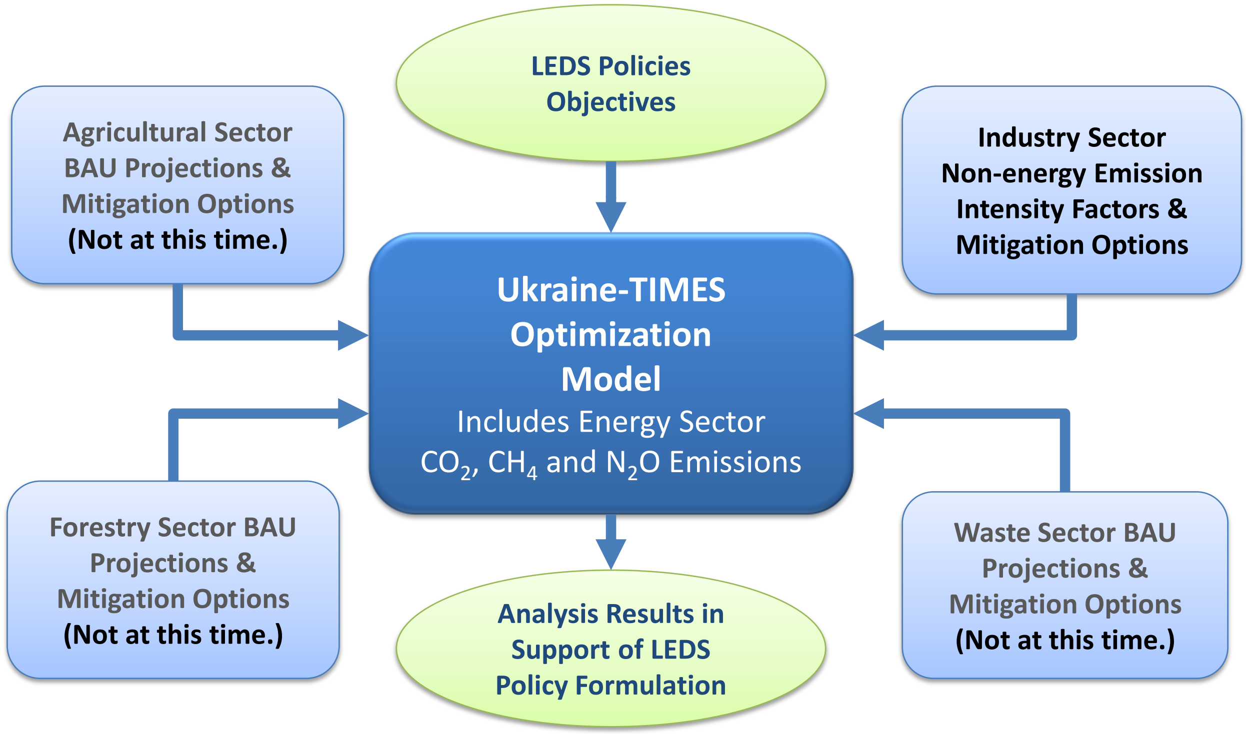

Figure 2

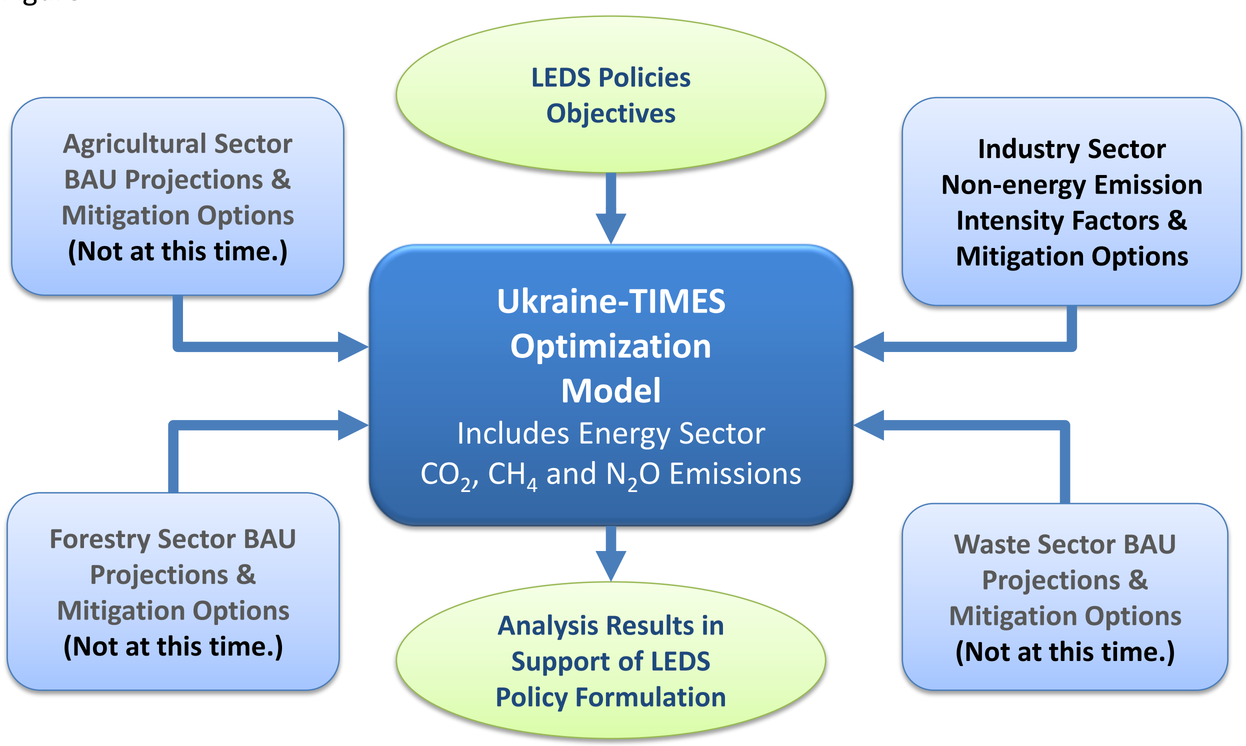

Figure 2provides an overview of the integrated approach, which is described in more details in the following sections. As noted above, only the energy sector GHG emission and non-energy emissions from industrial processes will be incorporated initially.

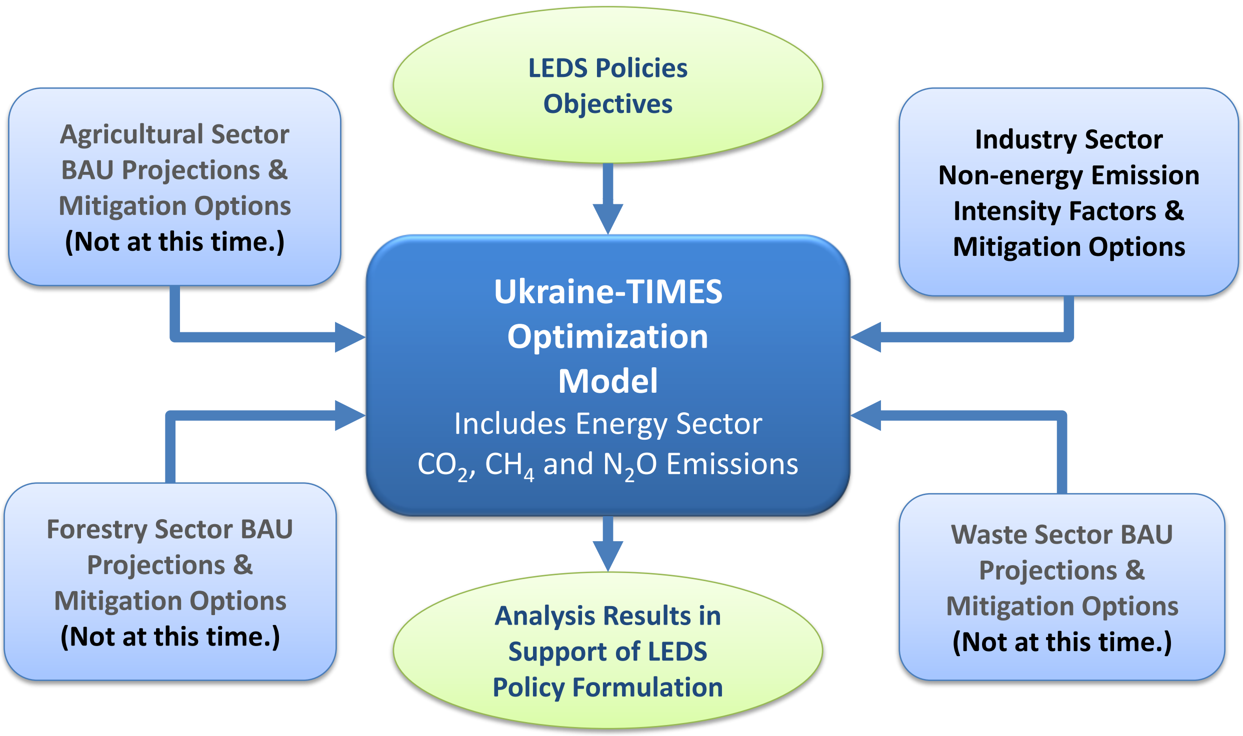

Figure 2 : Approach to Fully Integrated GHG Accounting and Mitigation Analysis with TIMES-Ukraine

Table 1: National Greenhouse Gas Inventories - Non-Energy Emissions – 2012

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6
	(Gg)		CO_2 equivalent (Gg)		(Gg)	
Total Non-Energy Emissions & Removals	**13,151.28**	**1,028.42**	**96.52**	**726.20**		**0.00048**
Total Industrial Processes	**40,397.18**	**36.62**	**10.69**	**726.20**		**0.00048**
A. Mineral Products	10,094.82					
B. Chemical Industry	6,542.35	10.98	10.69			
C. Metal Production	23,760.02	25.64		,		
F. Consumption of Halocarbons and SF_6				726.20		0.00048
Total Agriculture*		**503.14**	**82.15**			
A. Enteric Fermentation		421.86				
B. Manure Management		74.36	10.10			
C. Rice Cultivation		5.16				
D. Agricultural Soils (2)			70.05			
F. Field Burning of Agricultural Residues		1.76	0.05			
Total Land-Use Categories*	**-27,246.22**	**1.00**	**0.05**			
A. Forest Land	-63,123.69	0.93	0.037			
B. Cropland	32,562.59		0.0043			
C. Grassland	3,269.47	0.069	0.0063			
D. Wetlands	6.09		0.0013			
E. Settlements	39.31					
Total Waste*	**0.32**	**487.66**	**3.63**			
A. Solid Waste Disposal on Land		362.33				
B. Waste Water Handling		125.33	3.63			
C. Waste Incineration	0.32					

** Not being incorporated into TIMES-Ukraine at this time.*

Table 2: Industry Sector Non-Energy Greenhouse Gas Emissions – 2012

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6
	(Gg)		CO_2 equivalent (Gg)		(Gg)	
Total Industrial Processes	**40,397.18**	**36.62**	**10.69**	**726.20**		**0.00048**
A. Mineral Products	10,094.82					
1. Cement Production	3,217.12					
2. Lime Production	2,769.36					
3. Limestone and Dolomite Use	3,815.78					
4. Soda Ash Production and Use	146.60					
7. Glass Production	145.96					
B. Chemical Industry	6,542.35	10.98	10.69			
1. Ammonia Production	6,508.73					
2. Nitric Acid Production			10.52			
3. Adipic Acid Production			0.17			
4. Carbide Production	33.62	0.16				
5. Other		10.83				
C. Metal Production	23,760.02	25.64				
1. Iron and Steel Production	21,743.35	25.64				
2. Ferroalloys Production	2,016.66					
F. Consumption of Halocarbons and SF_6				726.20		0.00048

4.1 Industrial Process Non-Energy Emissions

Table 2 is as summary of the Non-Energy Greenhouse Gas Emissions from Industrial Processes. The following sections give details for each industry subsector.

4.1.1 Mineral Products

Mineral Products process-related, non-energy emissions come primarily from Cement Production, Lime Production, and limestone use, which in 2012 accounted for 97% of the non-energy CO_2 emissions from this industry subsector, as shown in Table 3.

Table 3: Mineral Products Non-Energy Greenhouse Gas Emissions – 2012

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSIONS
	Production/Consumption quantity		CO_2
	Description	(kt)	(Gg)
A. Mineral Products			**10,094.82**
1. Cement Production	Clinker production	6,279.20	3,217.12
2. Lime Production	Lime production	4,301.22	2,769.36
3. Limestone and Dolomite Use	Limestone and dolomite use	8,791.57	3,815.78
4. Soda Ash			146.60
Soda Ash Production	Soda Ash Production		
Soda Ash Use	Soda ach use	353.25	146.60
5. Asphalt Roofing	Asphalt roofing	8.00	
6. Road Paving with Asphalt	Road paving with asphalt	169.78	
7. Glass Production	Glass production	1,377.75	145.96

The Mineral Products industry subsector is modelled in TIMES-Ukraine as a series of technologies producing and transporting cement, producing lime (and limestone) and producing and transporting glass. Non-energy process emissions from this subsector can be linked to the projected demands for production of cement, lime and glass using an emission intensity factor, such as CO_2 per ton of cement, lime or glass produced. The emission intensity factors can be derived from 2012 data, which can be kept constant or adjusted over time based on inputs from local experts.

The BAU emissions projections for each of these sub-sectors would then be calculated using the emission intensity factor and the relevant TIMES-Ukraine demand projection, which is derived from activity data. These emissions would be represented in the model as a new process producing the non-energy CO_2, and mitigation options generating emission reductions for a cost can be used to enable these options to be included in the optimization.

Because TIMES-Ukraine does not contain any specific process information for cement, lime or glass production, the mitigation options will need to take the form of a mitigation cost curve, which can be derived from international data adapted to conditions in Ukraine.

4.1.2 Chemical Industry

Chemical Industry process-related, non-energy emissions come almost entirely from Ammonia Production, but Nitric Acid Production produces small amounts of N_2O, which has a GWP of 310. In addition, there are CO_2 and CH_4 emissions from carbide production, coke production and others as listed in Table 4.

Table 4: Chemical Industry Non-Energy Greenhouse Gas Emissions – 2012

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSIONS		
	Production/Consumption quantity		CO_2 Emissions	CH_4 Emissions	N_2O Emissions
	Description	(kt)	(Gg)		
B. Chemical Industry			**6,542.35**	**10.98**	**10.69**
1. Ammonia Production	ammonia production	5,049.1	6,508.73		
2. Nitric Acid Production	nitric acid production	2,336.9			10.52
3. Adipic Acid Production	adipic acid production	13.0			0.17
4. Carbide Production	carbide production		33.62	0.16	
Silicon Carbide	silicon carbide production		31.60	0.16	
Calcium Carbide	calcium carbide production and use		2.02		
5. Other (please specify)				10.83	
Carbon Black	carbon black production			0.95	
Ethylene	ethylene production			0.13	
Methanol	methanol production			0.28	
Coke	coke production	18,938.9		9.47	

The Chemical Industry is modelled in TIMES-Ukraine as an Ammonia production process and an Other Chemicals production process. Non-energy emissions from ammonia production can be linked to the projected demand for Ammonia Production, using an emission intensity factor, such as CO_2 per ton of product produced. The emission intensity factor can be derived from 2012 data, which can be kept constant or adjusted over time based on inputs from local experts. The remaining emissions in this subsector, with the exception of Coke production, will be aggregated and linked to the Other Chemicals demand projection and an emission intensity factor, calculated from the 2012 inventory data and the 2012 Other Chemicals demand level.

The BAU emissions projections for the ammonia and other chemicals sub-sectors will be calculated using the emission intensity factor and the TIMES-Ukraine demand projection. The BAU emissions related to Coke production can be tied to the coke production process in TIMES-

Ukraine using an appropriate emission factor for coke production, so that the BAU emissions will vary in proportion to the amount of coke the model chooses to produce.

As with Mineral Products, TIMES-Ukraine does not contain any Chemical Industry process information, and the mitigation options will need to take the form of mitigation cost curves, which can be derived from international data adapted to conditions in Ukraine and included in the optimization.

4.1.3 Metal Production

Metal Production produces significant non-energy related CO_2 emissions from both Iron and Steel production and Ferroalloys production, as shown in Table 5. No emissions are reported for Aluminum production.

Table 5: Industry Sector Non-Energy Greenhouse Gas Emissions – 2012

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSIONS		
	Production/Consumption quantity		CO_2 Emissions	CH_4 Emissions	N_2O Emissions
	Description [(1)]	(kt)	(Gg)		
C. Metal Production			**23,760.02**	**25.6**	
1. Iron and Steel Production			21,743.35	25.6	
Steel	steel production	32,286.6	4,147.8		
Pig Iron	iron production	28,486.6	17,595.6	25.64	
2. Ferroalloys Production	Ferroalloys Production	1,300.0	2,016.7		
3. Aluminum Production	Aluminum Production				

The Metal Production industry is modelled in TIMES-Ukraine as a set of industrial processes producing Aluminum, Iron and Steel and Other Non-Ferrous metals. All the emissions from Metals Production appear to come from the production of Iron and Steel or other Ferroalloys. Therefore, all non-energy emissions from this subsector will be linked to the projected demand for Iron and Steel products, using an emission intensity factor, such as CO_2 per ton of metals produced.

The BAU emissions projections for this sub-sector will be calculated using the emission intensity factor and the TIMES-Ukraine demand projection for Iron and Steel production. The emission intensity factor can be derived from 2012 data, which can be kept constant or adjusted over time based on inputs from local experts.

Similar to the other two industrial processes, the mitigation options will need to take the form of a mitigation cost curve, which can be derived from international data adapted to conditions in Ukraine.

4.1.4 Halocarbons

The final component of industrial process GHG emissions in Ukraine comes from emissions of halocarbons (specifically hydroflourocarbons, HFCs) from the use of Refrigeration and Air Conditioning Equipment and from SF6 used to produce certain electrical equipment. Although the size of this emission is small, HFCs and SF6 have very high GWPs, and so their emissions need to be tracked. Table 6 provides the emissions for specific HFC types and different end-use applications.

Table 6: Halocarbon Greenhouse Gas Emissions – 2012

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSIONS	
	Amount of fluid		From manufacturing	From stocks
	Filled into new manufactured products	In operating systems (average annual stocks)		
	(t)		(t)	
1. Refrigeration and Air Conditioning				
Domestic Refrigeration				
HFC-134a	6.64	784.31	6.64	3.92
Commercial Refrigeration				
HFC-125	2.24	32.61	0.05	4.89
HFC-134a	31.58	163.95	0.63	24.59
HFC-143a	1.90	34.95	0.04	5.24
Industrial Refrigeration				
HFC-125	0.00	200.77	0.00	32.41
HFC-134a	13.05	160.08	0.39	31.30
HFC-143a	0.39	25.03	0.00	4.88
HFC-32		149.09		22.36
Stationary Air-Conditioning				
HFC-125		519.28		25.96
HFC-134a				
HFC-32		519.15		25.96
Mobile Air-Conditioning				
HFC-125	0.02	0.37	0.00	0.06
HFC-134a	29.80	779.53	0.15	116.93
HFC-32	0.02	0.34	0.00	0.05

3. Fire Extinguishers				
HFC-125	10.96	8.36		3.70
HFC-227ea	9.39	46.53		2.17
4. Aerosols (Medical Inhalers)				
HFC-134a	23.69	85.43	IE	122.21
8. Electrical Equipment				
SF6	4.82	90.87	0.03	0.45

Several of these HFC emissions can be linked to the projected demand for air conditioning and refrigeration in buildings, industry and transport, and an emission intensity factor can be derived from 2012 data on leakage rates and the types of HFCs currently used in each sub-sector. The BAU emissions projections for each of these sub-sectors will be calculated using the emission intensity factor and the appropriate TIMES-Ukraine demand projection.

Domestic Refrigeration BAU emissions will be linked to the demand for combined demand for residential (urban and rural households) air conditioning and residential refrigeration. Commercial Refrigeration will be linked to the demand for combined demand for commercial air conditioning (large and small buildings) and commercial refrigeration.

Industrial Refrigeration and Mobile Air-Conditioning are not demand categories in TIMES-Ukraine, so independent development of their BAU emissions projections will be needed. Fire Extinguishers and Medical Inhalers also are not demand categories in TIMES-Ukraine, but they have relatively small emissions and can be ignored or modelled based on expert inputs in BAU emissions and potential mitigation measures.

SF6 emissions from manufacturing of electrical equipment need further clarification regarding the types of electrical equipment that generate these emissions and to see if their projected use is related to specific energy demands in TIMES-Ukraine.

The BAU emission intensity factor should be adjusted over time based on any currently required changes in HFCs types. Mitigation technologies could be included in the form of new cooling technologies using lower GWP refrigerants and/or having lower leakage rates.

4.2 Agriculture

The agriculture sector primarily produces GHG emissions of methane (CH_4) from enteric fermentation, manure management and rice cultivation, with important N_2O emissions from manure management and soil management, as shown in Table 7. As noted earlier, the Agriculture GHG emissions are not being explicitly incorporated into TIMES-Ukraine at this time. However, the information could then be entered into TIMES-Ukraine as part of expanding model coverage to all GHG sources in the country.

Table 7: Agriculture Sector Non-Energy Greenhouse Gas Emissions – 2012

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CH_4	N_2O
	(Gg)	
Total Agriculture	**503.14**	**82.15**
A. Enteric Fermentation	421.86	
1. Cattle	385.84	
Mature Dairy Cattle	301.93	
Mature Non-Dairy Cattle	5.97	
Young Cattle	77.94	
3. Sheep	10.36	
4. Goats	3.28	
5. Camels and Llamas	0.04	
6. Horses	6.95	
7. Mules and Asses	0.12	
8. Swine	11.21	
9. Poultry		
10. Other *(as specified in table 4.A)*	4.06	
Fur farming	0.11	
Rabbits	3.96	
B. Manure Management	74.36	10.10
1. Cattle	21.65	
Mature Dairy Cattle	16.72	
Mature Non-Dairy Cattle	0.67	
Young Cattle	4.26	
3. Sheep	0.43	
4. Goats	0.08	
5. Camels and Llamas	0.00	
6. Horses	0.54	
7. Mules and Asses	0.01	
8. Swine	43.84	
9. Poultry	7.08	
10. Other livestock	0.74	
Fur farming	0.29	
Rabbits	0.45	
11. Anaerobic Lagoons		0.0134
12. Liquid Systems		0.0195
13. Solid Storage and Dry Lot		10.07
14. Other AWMS		0.0002
C. Rice Cultivation	5.16	
1. Irrigated	5.16	
D. Agricultural Soils (2)		70.05

1. Direct Soil Emissions		50.47
2. Pasture, Range and Paddock Manure [(3)]		5.15
3. Indirect Emissions		14.43
F. Field Burning of Agricultural Residues (Cereals)	1.76	0.05
G. Other *(Indirect N_2O emissions from Manure Management)*		**1.95**

Enteric Fermentation: Cattle are the predominant source of methane from enteric fermentation, with swine and sheep making small contributions. BAU emissions from this subsector can be projected based on expected growth in livestock populations, feed types, and emission rates. The BAU emissions out to 2036 will need to be generated by local experts using approved methodologies at which time they would input to the model as a time series of emissions levels. Mitigation options would also need to be developed based on mitigation cost data from local and international sources for changing livestock feed types and/or practices.

Manure Management: Methane emissions from manure management are predominantly from swine and cattle with a small contribution from poultry. BAU emissions from this subsector can be projected based on expected growth in livestock populations, manure production and volatile solids data and methane generation potentials. Because actual methane production depends on how the manure is handled (dry, liquid slurry, anaerobic lagoon, etc.), and because mitigation options include other manure management practices, some of which capture methane for energy use, the development of the BAU emissions from this subsector will need to incorporate any expected changes in manure handling technologies under BAU assumptions. Once developed by a sector expert, the BAU emissions levels could be entered into the TIMES-Ukraine model as a time-series of emission levels. Mitigation technologies, such as composting and different forms of anaerobic digesters, would be developed from local and international data, and captured methane could be used within TIMES-Ukraine to substitute for other forms of energy for cooking, heating or electricity generation.

Soil Management: BAU emission projections for soil management emissions would be calculated outside TIMES-Ukraine based upon current emissions rates (derived from 2012 data) and the expected changes in agricultural acreage under production, using an approved methodology. Mitigation measures, such as Soil Carbon Management via No-Till/Conservation Tillage and Nutrient Management via Precision Agriculture and Use of Nitrification Inhibitors, would need to be developed based on mitigation cost data from local and international sources.

4.3 Land-Use Change & Forestry

There are five components to Land Use, Land-Use Change and Forestry emissions and removals: Forest land, Cropland, Grassland, Wetlands and Settlements. As shown in Table 8, the sector contains significant emissions and removals of CO_2, in addition to emissions of N_2O and CH_4. As noted earlier, the Land-Use and Forestry GHG emission are not being explicitly incorporated into TIMES-Ukraine at this time.

Table 8: Land Use and Forestry Non-Energy Greenhouse Gas Emissions – 2012

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2		CH_4	N_2O
	emissions	removals		
	(Gg)			
Total Land-Use Categories		**-27,246.22**	**1.00**	**0.05**
A. Forest Land		**-63,123.69**	**0.93**	**0.04**
1. Forest Land remaining Forest Land		-62,435.19	0.93	0.04
2. Land converted to Forest Land		-688.50		
B. Cropland	**32,562.59**			**0.00**
1. Cropland remaining Cropland	32,554.44			
2. Land converted to Cropland	8.15			0.00
C. Grassland	**3,269.47**		**0.07**	**0.01**
1. Grassland remaining Grassland	3,269.47		0.07	0.01
2. Land converted to Grassland				
D. Wetlands	**6.09**			**0.00**
1. Wetlands remaining Wetlands	6.09			
2. Land converted to Wetlands				0.00
E. Settlements	**39.31**			
Land converted to Settlements	39.31			

BAU emission and removal estimates would be generated by local experts based on expected changes in land use patterns within each component using approved methodologies. Mitigation options can include activities, such as forest retention programs, reforestation and afforestation activities, and urban forestry programs. The first two of these mitigation measures requires a program of action to evaluate in terms of forest land conserved, reforested, or afforested, and therefore increased CO_2 sequestration along with increased hardwood production and biomass resource production. Urban forestry provides CO_2 sequestration but it also reduces heating and cooling demands in urban buildings due to the shading and sheltering benefits of the urban trees. Cost and performance data for these and other possible mitigation measures would be generated by local and/or international experts based on international data adapted to Ukraine conditions. The information could then be entered into TIMES-Ukraine as part of expanding model coverage to all GHG sources in the country.

4.4 Waste

For Ukraine, emissions from this sector come from solid wastes and waste water handling, and consist primarily of CH_4 emissions with small N_2O emissions, as shown in Table 9.

Table 9: Waste Sector Non-Energy Greenhouse Gas Emissions – 2012

	CO_2	CH_4	N_2O

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	(Gg)		
Total Waste	**0.32**	**487.66**	**3.63**
A. Solid Waste Disposal on Land		**362.33**	
1. Managed Waste Disposal on Land		75.62	
2. Unmanaged Waste Disposal Sites		286.71	
3. Other *(as specified in table 6.A)*			
B. Waste Water Handling		**125.33**	**3.63**
1. Industrial Wastewater		39.28	0.25
2. Domestic and Commercial Waste Water		86.05	3.38
3. Other *(as specified in table 6.B)*			
C. Waste Incineration	**0.32**		**0.00**

Solid Waste: BAU emissions from this sub-sector would be estimated by local experts based on projections of per-capita solid waste generation, organic waste content estimates, and waste disposal methods. Mitigation measures can include shifting new waste to managed disposal sites, implementing waste reduction programs, installing land-fill gas (LFG) collection systems, and either flaring or using the captured LFG for heat or electricity production. Cost and performance of these options would be generated by local and/or international experts based on international data adapted to Ukraine conditions. The waste sector GHG emissions are being incorporated into TIMES-Ukraine for those activities that have energy related potential (e.g., municipal solid waste).

Waste Water: BAU emissions from this sector would be estimated by local experts based on projections of domestic, commercial and industrial waste water generation. Mitigation measures can include building new waste water treatment technologies and implementing waste water reduction programs. Cost and performance of these options would be generated by local and/or international experts based on international data adapted to Ukraine conditions. The Waste Water information could be entered into TIMES-Ukraine as part of expanding model coverage to all GHG sources in the country.

5 Data Requirements and Potential Mitigation Measures

The objective of this section of the repot is to start the process of collecting the data needed to incorporate full GHG accounting into the TIMES-Ukraine model so that it can be used as an integrated framework that can look across all sources of GHG emissions and identify the most cost-effective mitigation strategies that will meet national LEDS objectives.

5.1 Coal Mining Methane Emission Mitigation Measures

The TIMES-Ukraine model already has emission factors for methane releases from multiple sources of coal mining and produces the BAU emission projection as part of the Reference scenario.

Table 10 identifies 7 potential mitigation measures for coal mine methane emissions. Data will be sought on the following:

- Data available on any applications of these options to date in Ukraine,
- An assessment of which of the options below are applicable in Ukraine, and
- Identification of any additional options that are needed or appropriate to Ukraine.

Table 10: Potential Mitigation Measures For Coal Mine Methane Emissions

Technologies	Description	Applicability	Reduction Efficiency
Initial Mine Degasification and Capture	Coal mines recover methane using vertical wells drilled five years in advance of mining, horizontal boreholes drilled one year in advance, and gob wells. The captured methane is sold to a pipeline.	Applied to a portion of NEW underground, gassy mines only.	57%
Gob Gas Upgrade - Existing Mines	Gas recovery-and-use incremental to degasification and pipeline injection as well as spacing is tightened to increase recovery efficiency. Mines invest in enrichment technologies to enhance the gob gas that is sold to natural gas companies.	Applied to existing underground gassy mines that have installed degas systems.	77%
Gob Gas Upgrade - New Mines	= same =	Applied to new underground gassy mines that have installed degas systems.	77%
Flaring of Coal Mine Methane	Eliminate methane emissions from ventilation air using a flare. A pipeline is needed to transport the gas to a safe distance from the mine.	Applied to all underground, gassy mines.	98%
On/Off site Electric with Coal Mine Methane	Technology uses catalytic oxidation. Data taken from "Technical and Economic Assessment: Mitigation of Methane Emissions from Coal Mine Ventilation Air, EPA Feb 2000.	Applied to all underground mines with medium quality gas.	98%
On/Off site Process Heat with Coal Mine Methane	= same =	Applied to all underground mines with medium quality gas. The technology has not yet been implemented in the U.S.	98%
On/Off site Cogeneration with Coal Mine Methane	= same =	Applied to all underground mines with medium quality gas. The technology has not yet been implemented in the U.S.	98%

5.2 Natural Gas System Methane Emission Mitigation Measures

The TIMES-Ukraine model already has emission factors for methane releases from multiple sources of natural gas production, transmission and distribution and produces the BAU emission projection as part of the Reference scenario.

Table 11 identifies 35 potential mitigation measures for these emissions. Data will be sought on the following:

- Data available on any applications of these options to date in Ukraine,
- An assessment of which of the options below are applicable in Ukraine, and
- Identification of any additional options that are needed or appropriate to Ukraine.

There are clearly a lot of possibilities for mitigation of natural gas leaks, and these (and any other relevant options) should be organized and characterized as best fits the Ukraine natural gas infrastructure.

Table 11: Potential Mitigation Measures for natural Gas System Methane Emissions

Technologies	Description	Applicability	Reduction Efficiency
Compressed air pneumatic devices	Replacing high-bleed pneumatic devices (powered by natural gas) with compressed air systems will completely eliminate the methane emissions from these pneumatic devices.	The technology is applied to the projected production infrastructure needed to meet projected production.	100%
Low-bleed pneumatic devices	High-bleed pneumatic devices (powered by natural gas), which emit a high volume of methane to the atmosphere, can be replaced with low-bleed devices that emit far lower volumes of methane.	The technology is applied to the projected production infrastructure needed to meet projected production.	86%
Directed I&M of Pipeline Leaks	This directed inspection and maintenance option involves surveying Pipelines in the Production sector to identify sources of leaks and performing maintenance on leaks that are most cost effective to repair.	The technology is applied to the projected production infrastructure needed to meet projected production.	60%
Flash Tank Separators	A flash tank separator operates by reducing the pressure of methane rich tri-ethylene Glycol suddenly to cause the ab-orbed CH_4 to 'flash' or (vaporize). The flashed CH_4 can be collected and used as fuel gas or compressed and returned.	The technology is applied to the projected production infrastructure needed to meet projected production.	54%
Reduce Glycol Circulation Rates in Dehydr (Prod)	During production, tri-ethylene Glycol (TEG) is circulated through dehydrators to absorb water from the gas stream before entering the pipe-line. TEG also absorbs some methane that is vented. Reducing the glycol circulation rate to the optimal level will	The technology is applied to the projected production infrastructure needed to meet projected production.	31%
Directed I&M of Chemical Inspection Pumps	This directed inspection and maintenance (DI&M) option involves surveying Chemical Inspection Pumps at Production sites to identify sources of leaks and performing maintenance on leaks that are most cost effective to repair.	The technology is applied to the projected production infrastructure needed to meet projected production.	40%
Portable Evacuation Compressor for Pipeline Venting	This option relates to the use of pump-down techniques to lower the gas-line pressure before venting. An in-line portable compressor is used to lower line pressure by up to 90 percent of its original value without venting.	The technology is applied to the projected production infrastructure needed to meet projected production.	72%

Technologies	Description	Applicability	Reduction Efficiency
Installing Plunger Lift Systems In Gas Wells	A plunger lift uses the well's natural energy to lift the fluids out of the well to prevent blockage of gas wells due to fluid accumulation and helps maintain the production level, thus removing these liquids and reducing methane emissions.	The technology is applied to the projected production infrastructure needed to meet projected production.	4%
Installation of Electric Starters on Compressors	Small gas expansion turbine motors are used to start internal combustion engines for compressors, generators and pumps in the natural gas (NG) industry. These starters use compressed NG, which is vented to the atmosphere.	The technology is applied to the projected production infrastructure needed to meet projected production.	75%
Surge Vessels for Station/Well Venting	During production, a surge vessel can be used during blowdowns to avoid venting methane to atmosphere. The captured methane can be re-routed to the pipeline or used on site as fuel.	The technology is applied to the projected production infrastructure needed to meet projected production.	50%
Install Flares	Recovered methane is flared to reduce GHG emissions.	The technology is applied to the projected production infrastructure and ro compressor stations.	95%
Fuel Gas Blowdown Valve	When a system is depressurized, emissions can result from "blow down", or venting of the high-pressure gas left within the compressor. Using a fuel gas retrofit, methane that would be vented during a blow down can be routed to a fuel gas system and avoid	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	33%
Catalytic Converter	A catalytic converter is an afterburner that reduces methane emissions resulting from incomplete combustion. Methane is combusted, and the energy produced is unused. Consequently, the benefits are restricted to the value placed on reducing methane.	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	56%
Dry Seals on Centrifugal Compressors	Some centrifugal compressors are fitted with 'wet' seals that use circulating oil at the pressure seal face to prevent methane emissions. 'Dry' seals use high-pressure gas to ensure sealing. Dry seals emit far less gas compared to wet seal systems. [Not	The technology is applied to the projected production infrastructure needed to meet projected production.	69%
Gas turbines replace reciprocating engines	Natural gas (NG) reciprocating engines are replaced with NG turbines. NG turbines have a better combustion efficiency compared to reciprocating engines; consequently, methane emissions are reduced.	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	90%
Static-Pacs on reciprocating compressors	A static-pac seal on a compressor rod eliminates rod-packing leaks during shutdown when the compressor is kept pressurized. An automatic controller activates when the compressor is shutdown to wedge a tight seal around the shaft; it deactivates the seal	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	6%

Technologies	Description	Applicability	Reduction Efficiency
Portable Evac. Compressor for Pipe. Vent	During processing and transmission, this option relates to the use of pump-down techniques to lower the gas-line pressure before venting. An in-line portable compressor is used to lower line pressure by up to 90 percent of its original value without ventilation.	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	72%
Directed I&M to Compressor Stations	This directed inspection and maintenance option involves surveying the Compressor Stations, within the Processing and Transmission sectors, to identify sources of leaks and performing maintenance on leaks that are most cost effective to repair.	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	13%
Enhanced I&M to Compressor Stations	This Enhanced directed inspection and maintenance (DI&M) option is a more aggressive DI&M program at P&T Compressor Stations that involves increased frequency of survey and repair. Enhanced DI&M costs more but also achieves greater savings by reducing lea	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	20%
Surge Vessels for Station/Well Venting	During processing and transmission, a surge vessel can be used during blowdowns to avoid venting methane to atmosphere. The captured methane can be re-routed to the pipeline or used on site as fuel.	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	50%
Reducing the Glycol Circulation Rates in Dehydrators	During P&T, tri-ethylene Glycol (TEG) is circulated through dehydrators to absorb water from the gas stream before entering the pipeline. TEG also absorbs some methane, which is vented.	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	30%
Compressors-Altering Start-Up Procedure during Maintenance	Instead of shutting down centrifugal compressors during "cleaning" maintenance, the turbines are cleaned while on-line (running). This procedure reduces the number of compressor depressurizations required per year.	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	100%
Directed I&M to Transmission Pipeline	This directed inspection and maintenance option involves surveying Pipelines within the Transmission sector to identify sources of leaks and performing maintenance on leaks that are most cost effective to repair.	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	60%
Installation of Flash Tank Separators	During P&T, a flash tank separator operates by reducing the pressure of methane rich tri-ethylene Glycol suddenly to cause the absorbed methane to 'flash' or (vaporize). The flashed methane can be collected and used as fuel gas or compressed and returned	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	61%
Install Flares	Recovered methane is flared to reduce GHG emissions.	The technology is applied to the projected production infrastructure and compressor stations.	95%

Technologies	Description	Applicability	Reduction Efficiency
ClockSpring Repair Kits	Methane emissions resulting from venting of pipes that require repair are eliminated with this repair technique that does not require the pipe to be vented.	The technology is applied to the projected transmission system.	50%
Redesign Blowdown	Methane is would normally be vented during system or equipment over-pressure situation is captured for use within the process plant	The technology is applied to the projected process plants system.	95%
Hot Taps	Methane that would normally be vented to allow welding of new pipe openings are avoided because these taps can be connected while the pipe is in operation..	The technology is applied to the projected transmission system.	75%
Directed I&M to Distribution	This directed inspection and maintenance option involves surveying Distribution facilities (e.g., gate, meter and regulating stations) and associated equipment to identify sources of leaks and performing maintenance on leaks that are most cost effective t	The technology is applied to the projected distribution infrastructure needed to meet consumption.	26%
Enhanced I&M to Distribution	DI&M is a method for identifying and reducing leaks. This Enhanced DI&M option is a more aggressive program at Distribution facilities that involves increased frequency of survey and repair. Enhanced DI&M costs more but also achieves greater savings by re	The technology is applied to the projected distribution infrastructure needed to meet consumption.	66%
Electronic Monitor at Service Facilities	Natural gas distribution systems operate at gas pressures that are higher than necessary to ensure that both peak and non-peak operating pressures are met. With electronic monitoring, the distribution system pressure can match real time demand and reduce	The technology is applied to the projected distribution infrastructure needed to meet consumption.	95%
Replacement of Iron/Unprotected Steel Pipes	Cast iron and unprotected steel pipeline are prone to corrosion and leaks. They should be replaced with pipeline made of non-corrosive material that will reduce methane losses from the distribution system.	The technology is applied to the projected distribution infrastructure needed to meet consumption.	95%
Replacement of Unprotected Steel Services	Unprotected steel services are prone to corrosion and leaks. They should be replaced with services made of non-corrosive material, such as plastic or protected services, which will reduce methane losses from the distribution system.	The technology is applied to the projected distribution infrastructure needed to meet consumption.	95%
Use smart regulators/clocking solenoids	Leaks in steel services are can be reduced by better regulators that avoid pressure swings caused by changes in demand.	The technology is applied to the projected distribution infrastructure needed to meet consumption.	95%
Leak detection/walking surveys	Unprotected steel services are prone to corrosion and leaks. Increased surveillance will reduce methane losses from the distribution system.	The technology is applied to the projected distribution infrastructure needed to meet consumption.	95%

5.3 Industrial Processes

Section 3 proposes that the Industrial Process non-energy emissions be sub-divided into the following sub-sectors.

- Cement production
- Lime and Limestone production
- Glass production
- Ammonia production
- Other Chemicals production
- Coke production
- Iron & Steel production
- Halocarbon Consumption from:
    - Domestic air conditioning and refrigeration
    - Commercial air conditioning and refrigeration
    - Industrial refrigeration
    - Transport air conditioning
- SF6 production

For each of the above sub-sectors, the following types of data are required.

1. Data describing the processes used by existing facilities. This data will be used to calculate likely mitigation cost-curves for current facilities.
2. Identification of potential growth/change in each sub-sector to cross-check against the demand projections in TIMES-Ukraine.

For each major production facility the following data needs to be provided.

Capacity: how much the facility can produce in a year, at maximum utilization.

Utilization: fraction of the facility's capacity used in the most recent year(s) for which data is available.

2012 Production level: facility output for 2012 in natural units.

Process information: description of the process type, i.e., wet or dry kiln, chemical composition of clinker, etc.

Age: facility age.

Condition: What is the facility's condition? Has it recently undergone major repairs or upgrades, or are upgrades required in the near term? If so, describe in detail.

Other considerations: Specify as needed.

This raises questions like: *Is there much international competition? What is the elasticity of cement production to GDP, if known?* This information will be used to cross-check likely industry growth with the TIMES-Ukraine demand projection.

Data will be sought from local industry expert that have emission mitigation cost data for the facility types and conditions in Ukraine. The resulting cost-mitigation curves should encompass mitigation measures, such as reducing clinker share in cement as well as reducing limestone share in clinker by using additives. The expert may make additional data requests after reviewing the data and may meet with SWG members during their trip to Ukraine.

5.4 Halocarbon Consumption and SF6 Production

Section 3 proposes that halocarbon consumption and SF6 production emissions are tentatively to be sub-divided into the following sub-sectors.

- Domestic air conditioning and refrigeration
- Commercial air conditioning and refrigeration
- Industrial refrigeration
- Transport air conditioning
- SF6 production

A final determination will be made following further discussion with UNAS/IEF.

The 2012 GHG inventory provides data on the types of HFCs that are currently in use for air conditioning and refrigeration equipment in Ukraine. This data will be used to calculate the BAU emission intensity factors for each of the above sub-sectors. The following data is requested to support development of the BAU projection and potential mitigation options.

This raises question, *Are there existing requirements to change HFC types in new air conditioning and refrigeration equipment?* In the absence of any changes, the 2012 BAU emission intensity factor would be assumed to remain constant over time based.

An international industry expert will be consulted to identify the new cooling technologies available internationally that using low-GWP refrigerants and/or having lower leakage rates.

5.5 Additional Industrial Process Emission Mitigation Measures

As noted above most mitigation measures will focus on reducing emission levels through process improvements. However, given the large volumes of CO_2 produced by some industries, there are a few general mitigation measures available that would use rather than release the CO_2. These include: production of carbamide; sale or use in green houses for enhancing plant growth, and injection into depleted oil and natural gas fields for enhanced oil recovery or permanent storage. This raises questions regarding the Ukraine situation in this area.

1. *Are greenhouses attractive in Ukraine, and do they represent a market for CO_2 from process industry sources? If so, what are the likely capture and distribution infrastructure costs needed to create this new product?*
2. *Are there depleted oil or gas fields that would benefit from enhanced recovery techniques using CO_2? If so, what are the likely capture and distribution infrastructure costs needed to get CO_2 from industrial and power plant sources?*

3. *Are there depleted oil or gas fields that are suitable as permanent CO_2 storage sites?*

6 Agricultural sector

The agriculture sector primarily produces GHG emissions of methane (CH_4) from enteric fermentation, manure management and rice cultivation, with important N_2O emissions from manure management and soil management.

6.1 Enteric Fermentation:

Cattle are the predominant source of methane from enteric fermentation, with swine and sheep making small contributions.

A BAU projection of enteric fermentation emissions is needed, if available. Otherwise, provide the following data that will be used by an international expert to calculate the BAU projection. *What are the projected changes in livestock population for these three species? What emission factor was calculated for each species in the 2012 inventory? Are the 2012 emission factors for cattle likely to change due to expected changes in feed types?*

6.2 Manure Management

Methane and N_2O emissions from manure management are almost entirely from cattle and swine with a small contribution from poultry.

A BAU projection of manure management emissions is needed, if available. Otherwise, provide the following data that will be used by an international expert to calculate the BAU projection. *What is the methane generation potential calculated for 2012 for each of these livestock populations? What methane conversion factors were calculated for each manure treatment type in the 2012 inventory? What is the current portion of manure from each species managed by each system type? Is that proportion expected to change in the BAU projection? What is investment cost of an anaerobic digestion system to manage cattle manure?*

6.3 Rice Cultivation

Rice cultivation emissions come entirely from CH_4 generated from paddy fields when they are flooded.

A BAU projection of rice cultivation emissions needs to be provided, if available. *Otherwise, provide the following data that will be used by an international expert to calculate the BAU projection. What is the projected growth in land used for rice cultivation?*

6.4 Soil Nutrient Management

N_2O emissions come entirely from nutrient application and soil management. The BAU emission projections would be calculated based upon current emissions rates (derived from 2012 data) and the expected changes in agricultural acreage under production, using an approved methodology.

A BAU projection of nutrient management emissions needs to be provided, if available. *Otherwise, provide the following data that will be used by an international expert to calculate the BAU projection. What are the expected changes in agricultural acreage under production?*

Mitigation measures to be considered include:

- Soil Carbon Management via No-Till/Conservation Tillage, and
- Nutrient Management via Precision Agriculture and Use of Nitrification Inhibitors.

Table 12 and Table 13 provide key input parameters that are needed to characterize measures. Much of the data, such as soil carbon accumulation rates and fuel reduction factors can come from an international agriculture expert. However, any local data will be very useful such as these. *What local data exists regarding no-till and conservation till practices in Ukraine? What local data exists regarding Precision Agriculture practices or Nitrification Inhibitors? Is the land area utilizing any of the above practices expected to grow in the BAU scenario?*

Table 12: Parameters for Soil Carbon Management via No-Till/Conservation Tillage

Parameter	Units
No-Till Area	hectares
Conservation Till Area	hectares
No-Till Soil Carbon Accumulation Rate	tCO2e/ha-yr
Conservation Till Soil C Accumulation Rate	tCO2e/ha-yr
No-Till Fuel Reduction	tCO2e/ha-yr
Conservation Till Fuel Reduction	tCO2e/ha-yr
Gallons Diesel Reduced, No-Till	gal/ha-yr
Gallons Diesel Reduced, Cons. Till	gal/ha-yr
Diesel Direct Combustion Emission Factor	tCO2e/gal
Diesel Fuel Cycle EF	tCO2e/gal
Potential Yield Loss	%
Value of Crop Production	$/ha
Diesel Fuel Cost	$/gal
Fixed and Other Variable Costs	$/gal

Table 13: Parameters for Nutrient Management via Precision Agriculture and Use of Nitrification Inhibitors

Parameter	Units
Targeted Area for Precision Ag	Mha
Targeted Area for Nitrification Inhibitors	Mha
N Fertilizer Rate Reduction Benefit	tCO2e/ha-yr
PA N Fertilizer Reduction %	%
NI N Fertilizer Reduction %	%
Avg. Cost of N Fertilizer	($/short ton)
Cost Increase of Fertilizer N with Nitrifications Inhibitors	%

Growth Rate in Fertilizer Costs	%/yr
N Fertilizer Application Rate	lb N/acre
PA Capital Equipment Costs	$/acre
NI Material Costs	$/acre

7 Land-Use Change & Forestry

There are five components to this sector:

- Forest land;
- Croplands;
- Grasslands;
- Wetlands, and
- Settlements.

Forest lands produce significant removals of CO_2 along with small emissions of CH_4. Croplands and Grasslands generate significant emissions of CO_2, while Wetlands and Settlements produce small amounts of CO_2. BAU emission and removal estimates need to be generated by local experts based on expected changes in land use patterns within each component using approved methodologies.

A BAU projection of land use change and forestry emissions needs to be provided, if available. Otherwise, provide the following data that will be used by an international expert to calculate the BAU projection. *What are the expected changes in land use patterns within each component? What emission/retention factors are available and applicable from the 2012 inventory work?*

Forest land mitigation options can include activities, such as forest retention programs, reforestation and afforestation activities, and urban forestry programs. *Are there any current programs regarding any of these mitigation actions that can provide cost and performance data regarding increased CO_2 sequestration? In the case of Urban forestry, is there any data on the likely reductions in heating and cooling demands in urban buildings due to the shading and sheltering benefits of the urban trees?*

8 Waste

For Ukraine, emissions from this sector come from solid wastes and waste water handling, and consist primarily of CH_4 emissions with small N_2O emissions.

8.1 Solid Waste

BAU emissions from this sub-sector need to be estimated by local experts based on projections of per-capita solid waste generation, organic waste content estimates, and waste disposal methods.

A BAU projection of solid waste emissions needs to be provided, if available. Otherwise, provide the following data that will be used by an international expert to calculate the BAU projection. *What data is available regarding per-capita solid waste generation, organic waste content estimates, and waste disposal methods?*

Mitigation measures can include shifting new waste to managed disposal sites, implementing waste reduction programs, installing land-fill gas (LFG) collection systems, and either flaring or using the captured LFG for heat or electricity production. *What data exists regarding the cost and performance of these options in Ukraine?*

8.2 Waste Water

BAU emissions from this sector would be estimated by local experts based on projections of domestic, commercial and industrial waste water generation.

A BAU projection of waste water emissions needs to be provided, if available. Otherwise, provide the following data that will be used by an international expert to calculate the BAU projection. *What data is available regarding projections of domestic, commercial and industrial waste water generation?*

Mitigation measures can include building new waste water treatment technologies and implementing waste water reduction programs. *What data exists regarding the cost and performance of these options in Ukraine?*

9 GHG Data

The following 100-year global warming potential (GWP) factors[2] will be used to combine all emissions in CO_2 equivalent units.

Table 14: IIPCC 100-yr Global Warming Potentials

Greenhouse Gas	Lifetime (years)	GWP time horizon	
		20 years	100 years
Methane	12.4	56	21
Nitrous oxide	121	280	310
HFC-134a	13.4	3400	1300

[2] http://unfccc.int/ghg_data/items/3825.php

10 Naming Convention for Non-Energy Emissions

Table 15 provides a set of emission names for incorporation into the TIMES-Ukraine model. These emission commodity names use the following naming conventions to allow logical sorting, grouping and filtering within the model and its result reporting software.

Table 15: Industry Sector Non-Energy GHG Emission Names

TIMES-Ukraine Demand	CO_2 Emission Commodity	CH_4 Emission Commodity	N_2O Emission Commodity	HFC Emission Commodity	SF6 Emission Commodity
Ammonia Products Demand	CO2ICHA	CH4ICHA	N2OICHA		
Other Chemicals Demand	CO2ICHO		N2OICHO		
Cement Demand	CO2IMNC				
Glass Products Demand	CO2IMNG				
Iron and Steel Products Demand	CO2IMTS	CH4IMTS			
Lime Demand	CO2IMNL				
Other Non Ferrous Metals Demand	CO2IMTO				
Other Non Metallic Minerals Demand	CO2IMNO	CH4IMNO			
Residential Air Conditioning				HFCRAC	
Residential Refrigeration				HFCRRF	
Commercial Air Conditioning				HFCCAC	
Commercial Refrigeration				HFCCRF	
Industrial Refrigeration				HFCIND	
Mobile Refrigeration				HFCMOB	
Electrical Equipment					SF6ELC
Coke Production		CH4ICHC			
Enteric fermentation		CH4ENT			
Manure Management		CH4MMG	N2OMMG		
Rice Cultivation		CH4RIC			
Agricultural Soils			N2OAGS		
Burning od Agricultural Residues		CH4BAR	N2OBAR		
Forest Lands	CO2FST	CH4FST			
Croplands	CO2CPL				
Grasslands	CO2GRL	CH4GSL			
Wetlands	CO2WTL				
Settlements	CO2STL				
Solid Waste Disposal		CH4SWD			
Wastewater Handing		CH4WWH	N2OWWH		
Waste Incineration	CO2WIN				